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DNA barcoding for novices: A quick tour and hands-on look at DNA barcoding CUREs designed for first-year students

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Thanks to its ease of use and amenability to generating open-ended research questions, DNA barcoding is one viable method to embed authentic research experiences in first-year courses. The Department of Biology at James Madison University (JMU) and the Cold Spring Harbor DNA Learning Center have developed several cost-effective, scalable, and transferable, DNA barcoding-based research experiences designed for introductory biology labs. This short article of our Mini Workshop provides a quick overview of the content of these DNA barcoding lab activities as well as links to resources that can aid in their implementation at your institution.

Keywords: CURE, DNA Barcoding, first year, freshman, bioinformatics, BLAST, DNA sequencing, gene trees

Introduction

Growing calls in science education reform have emphasized wide-scale engagement of first-year undergraduate students in authentic research experiences; however, large course enrollments, inadequate student experience, limited resources, and departmental inertia often create obstacles to reaching this goal (NASEM, 2017). To help overcome these obstacles, the Cold Spring Harbor DNA Learning Center, and Department of Biology at James Madison University (JMU) have developed cost-effective, scalable, and transferable DNA barcoding-based activities designed for first-year, introductory biology students (e.g., Hyman et al. 2019). In these activities, first-year students use DNA barcoding to engage in research practices drawn from the fields of ecology, molecular biology, and bioinformatics. In this article, we provide descriptions and links to three published lesson plans that have been implemented in first-year biology curricula:

- *DNA Barcoding Mosquitos*: A ~2-3-hour computer-based activity, designed to teach first year students how to analyze DNA barcode sequences from mosquitos.
- *DNA Barcoding 101*: A 3–4-week DNA barcoding lab that includes wet lab (DNA extraction, PCR, Gel Electrophoresis, DNA sequencing) activities and computer-based DNA barcode analyses.
- *Full Semester DNA Barcoding CURE*: A 14-wk CURE that is implemented in a first-year course at JMU that includes teaching materials tailored for first-year students and first-time instructors.

These resources and lesson plans will be useful to instructors or institutions interested in engaging introductory biology students in authentic DNA barcoding-based research in the classroom.

DNA Barcoding Mosquitos

This activity includes instructions for a freshman to senior level 120-minute bioinformatics lab in which students will learn how to use the DNA Subway (http://www.dnasubway.org) Blue Line. The DNA Subway Blue Line is a free, online educational bioinformatics platform for analyzing DNA barcoding data to determine the taxonomic identity of an organism and examine inferred phylogenetic relationships among species. The data analyzed in this exercise are a collection of mosquito DNA sequences generated by students at James Madison University. Identification of a mosquito's genus is important because different mosquito species can carry different pathogens, some of which cause deadly human diseases. The lesson plan can be found here: http://dx.doi.org/10.25334/Q4J111

DNA Barcoding 101

These activities include detailed instructions for a freshman to senior level set of labs that typically require 3-4 120-minute meetings. In these activities, students collect and photograph an organism to be DNA barcoded. They spend the first lab extracting and PCR amplifying DNA from their sample. In the following meeting, students use gel electrophoresis to identify successfully amplified samples and send them off for DNA sequencing. In the final lab, students analyze their DNA barcode sequences in the DNA Subway Blue Line (http://www.dnasubway.org). Lesson plans, materials, and worksheets can be found here: https://dnabarcoding101.org/resources/

Full Semester DNA Barcoding CURE

These activities include instructions for a freshman-level set of labs that typically take 14 170-minute lab periods. In these labs, students sample organisms from forest edges and interior habitats in a campus arboretum and use DNA barcoding to catalog and compare species diversity in these habitats. These labs can be adapted to identify specific taxonomic groups (ex. mosquitos), habitats (ex. urban parks), or questions relevant to your research or location. Detailed lesson plans, slide decks, syllabi, rubrics, worksheets, and a more thorough discussion of alternative implementations of these labs can be found here: https://doi.org/10.24918/cs.2019.10

Materials

In general, the wet lab portions of DNA barcoding require access to a lab space with basic molecular biology equipment (micropipettors, PCR thermocycler, microcentrifuge, vortexer, etc). Analyzing DNA barcode sequences requires access to an internet connected computer. Detailed lists of wet lab materials, equipment, and costs can be found in "*S0.3: DNA barcoding equipment list.xls*" at https://doi.org/10.24918/cs.2019.10
or at https://dnabarcoding101.org/resources/

Notes for the Instructor

Although some experience with DNA extraction, PCR, gel electrophoresis, and DNA sequencing is beneficial, it is not required to complete these labs. We have tailored all these resources to be user friendly and accessible to any instructor with a general background in biology. If you are considering implementing these labs, but want further help or instruction we highly encourage you to reach out to the authors or sign up for a training workshop offered through the Cold Spring Harbor Lab DNA Learning Center:
https://dnalc.cshl.edu/programs/teacher_training.html

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About the Authors

Oliver Hyman, Elizabeth Doyle, and Andrea Pesce are lecturers at James Madison University where they teach and coordinate large introductory courses and CUREs.

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Mission, Review Process & Disclaimer

The Association for Biology Laboratory Education (ABLE) was founded in 1979 to promote information exchange among university and college educators actively concerned with teaching biology in a laboratory setting. The focus of ABLE is to improve the undergraduate biology laboratory experience by promoting the development and dissemination of interesting, innovative, and reliable laboratory exercises. For more information about ABLE, please visit http://www.ableweb.org/.

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